The Industrial Organization of Utility Energy Efficiency Programs*

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Abstract

Many of the energy efficiency programs available to homeowners and businesses are sponsored by utilities. The rationale for delegating the achievement of energy saving objectives to utilities is however unclear. In this paper, we seek to understand why and when utility-sponsored programs could be socially-preferable to government-led programs. We develop an industrial organization model with imperfectly informed energy users in which a utility is required to meet an exogenous energy efficiency policy objective. The model is then used to evaluate the welfare impacts of the programs that emerge in equilibrium. We show that the utility can reduce program costs and implement welfare-improving solutions, in particular, because it can credibly signal the energy performance of energy efficiency contractors.
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1 Introduction

Many of the energy efficiency programs available to homeowners and businesses are sponsored by utilities. This approach was first implemented in the United States in the 1970-1990s in the wake of the first oil crisis (Joskow and Marron, 1992; Gillingham et al., 2006; Auffhammer et al., 2008). Europe followed in the 2000s in a context of liberalization of energy markets and

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growing concerns about energy-related externalities. The adoption of the 2012 EU Energy Efficiency Directive in 2012 accelerated the diffusion of these utility-sponsored programs.

In practice, utilities rely on a wide range of instruments and tools to achieve energy savings: energy education, low to no-cost weatherization service and home energy audits, cash rebates and loans for higher efficiency equipment and for whole building efficiency upgrades. They also form partnerships with firms along the energy efficiency supply chain offering certification and create vetted contractor networks (see https://guep.org/utility-energy-efficiency-program-examples for US examples and www.dsireusa.org for comprehensive information on US energy efficiency programs). Importantly for our analysis, all of these instruments are not specific to utility programs. In other instances, or even in parallel with utility programs, public authorities also subsidize energy efficiency investments, manage energy labels, launch information campaigns...

A utility encouraging its customers to use less energy and reduce their energy bills might seem counter-intuitive at first glance. Self-interest may be part of the motivation. In particular, reducing peak demand lowers power generation costs. However, utility demand-side management is mainly driven by policy incentives and obligations. In some cases, the legislator impose long-term targets that energy suppliers must meet through customer energy efficiency programs. In the US, 26 US states have such energy efficiency resource standard as of early 2017 (ACEEE https://aceee.org/topics/energy-efficiency-resource-standard-eers). In Europe, similar obligations are in place in Belgium, France, Italy, UK, and Poland. In other cases, energy savings targets are set by the energy regulator. Unlike their American counterpart, European utility-sponsored programs – also known as white certificates – allow the trading of energy savings among obliged parties (Langniss and Praetorius, 2006; Mundaca et al., 2008; Giraudet and Finon, 2015).

Despite their widespread adoption, the rationale for delegating the achievement of energy-saving objectives to utilities or other energy suppliers, is unclear (Brennan, 2013). From a general interest's perspective, what are the benefits for having energy suppliers designing and implementing the instruments and tools necessary to meet energy efficiency goals? Is it more cost-efficient than a, perhaps more conventional, approach where public authorities directly target energy users? Is it welfare-improving? The economic literature on energy efficiency is almost silent on these issues (for a recent survey, see Gerarden et al. 2017).

In this paper, we seek to understand why and when utility-sponsored programs could be socially-preferable to government-led programs. We develop an industrial organization model with imperfectly informed energy users in which a utility is required to meet an exogenous energy efficiency policy objective. The setting endogenizes the utility's energy efficiency instrument choices. The model is then used to evaluate the welfare impacts of the programs that emerge in equilibrium.

We start from the notion of energy services put forward by Gillingham et al. (2009), Fouquet and Pearson (2006), and others. In practice, consumers do not derive utility from energy per se, but from energy services such as space heating, lighting, mobility. For producing these services, they combine energy and durable goods (e.g. boilers, light bulbs, cars). By extension, these durables include investments made in weatherization or building energy retrofits. Almost all the measures included in actual EE programs precisely seek to influence the functioning of these durable-good markets. For instance, cash rebates reward the purchase of energy-efficient goods; certification of energy efficiency contractors mitigate information asymmetries; energy education informs energy users about the energy performance of certain goods and practices. This leads us to propose a conceptual framework which integrate both an energy market and an energy-using durable good market.

More specifically, the model describes the interactions between a continuum of consumers, an energy supplier, and two firms competing in a vertically differentiated market for energy-consuming durables. The base version of the model features two market imperfections: the energy supplier has market power (to simplify, we consider the monopoly) and there is information asymmetry over the energy performance of the durable good between consumers and the manufacturers.[1] The energy supplier is required to meet an exogenous energy efficiency target and we assume that three instruments are available: increasing the energy price, subsidizing the purchase of the energy-efficient good, and disclosing the quality of the energy-efficient good

[1]We also discuss how consumer behavioral anomalies and un-priced externalities may affect the results.

(certification).

We show that when there is no obligation, the impossibility of observing quality prevents companies from producing good quality and allows the energy producer to increase its sales. It has no interest in distributing subsidies to promote good quality. Certifying a product as high quality is beneficial for the energy producer, but it is not credible because consumers anticipate that it is in the consumer's interest to certify a product of poor quality as good. For a third party too, certification is profitable but not credible. On the other hand, when the regulator imposes restrictions on the energy supplier's sales, it is in the energy supplier's interest to certify the product of good quality to meet this obligation. Certification is credible because consumers anticipate that the energy provider has no interest in certifying a poor quality product instead because it could no longer comply with the constraint. On the other hand, certification by a third party is still not credible. Finally, certification by the energy provider is welfare-improving.

As shown by the recent survey by Gerarden et al. (2017), a large body of empirical works examine how energy users respond to energy price changes, financial incentives, energy education, labeling, standards, but regardless of who designs and implements these instruments. Fewer empirical studies examine the effect of the same instruments on durable good suppliers, in particular, household appliance manufacturers (Cohen et al., 2017; Houde 2018) and car makers (Sallee and Slemrod 2012; Ito and Sallee, 2018, Reynaert, 2017). How various instruments influence energy durables markets is also addressed in a few theoretical studies (Fischer, 2005; Giraudet and Quirion, 2008).

In contrast, the literature on the governance of utility EE efficiency programs is much scarcer. In a seminal contribution, Lewis and Sappington (1992) focus on the relationship between the regulator and the utility in a principal-agent framework. Assuming that the regulator is imperfectly informed about consumer preferences, they derive the optimal delegation rule. Chu and Sappington (2012, 2013) recently published two papers along the same normative vein. Wirl (2015) also identifies the optimal delegation mechanism, adding a second source of asymmetric information between the utility and the consumers. Our approach is less normative. We assume an exogenous delegation rule – the energy efficiency target – and we evaluate welfare consequences by investigating the impact of this rule on utility, consumer, and manufacturer choices. In contrast with all these contributions, we also account for the market for energy-using durable goods. Note that we rule out the possibility for utilities to trade energy savings obligations in the base version of the model, but we discuss how it would affect the findings.[2]. Last, our results will also be useful to interpret empirical results on the cost-effiency of energy efficiency programs (a set of studies pioneered by Joskow and Marron, 1992; then, Laughran and Kulick, 2004; Auffhammer et al., 2008; Arimura et al., 2012; see Gillingham et al., 2006, for a review).

The remainder of the paper is structured as followed. Section 2 presents the modeling assumptions. Section 3 analyzes the equilibrium without utility demand side management depending on the information structure. Section 4 studies the equilibrium with utility demand side management. Section 5 concludes.

2 The model

In the section, we lay out the model and elicit basic mechanisms in the absence of a cap on energy sales.

2.1 Set-up

We consider an economy of energy services (e.g., heating, cooling) involving two markets – a market for energy (e.g., natural gas, electricity) and a market for an enabling asset (e.g., a boiler, an air conditioner). Consumers have heterogeneous demand for energy services, determined by idiosyncratic preferences and income constraints. Demand is satisfied through the joint consumption of energy and the enabling asset. We focus on complex assets which are both supplied and installed by a contractor. The key component of the model is that the quality of installation is unobservable and affects the performance of the asset – which we interpret as its energy efficiency. For instance, issues in duct sealing will go unnoticed to the

[2] This aspect is adressed in qualitative terms by Langniss and Praetorius, 2006; Mundaca et al., 2008

consumer yet cause her to over-load her boiler to achieve a desired level of thermal comfort. To capture this credence-good dimension, we assume that the enabling asset is supplied by a vertically differentiated duopoly, with diligent installation being the relevant dimension of quality. To fix ideas, we further assume that energy is supplied by a monopolist; in the later analysis, we comment on simpler settings when relevant.

Consumers form a continuum of mass 1. They are each characterized by an idiosyncratic energy need x, uniformly distributed over [0,1]. For simplicity, we focus on the decision to install an asset, which can be installed poorly (hereafter low-quality good L) or diligently (hereafter high-quality good H). The utility consumer x derives from the purchase and operation of the asset is:

$$
\begin{aligned}
&u_L(x) = V - xp_e - p_L && \text{upon purchasing good } L,\\
&u_H(x) = V - p_H && \text{upon purchasing good } H,\\
&0 && \text{if no purchase.}
\end{aligned}
$$

with p_e the price of energy, p_H the price of good H, p_L the price of good L and V a fixed value derived from the energy service (e.g., thermal comfort). Consumers face energy expenditure $x \times p_e$ upon purchasing good L; without loss of generality, we normalize energy expenditure to zero upon purchasing good H. The two goods are supplied by two contractors, indexed by 1 and 2. Consumers take the best offer, so that $p_L = \min(p_{1L}, p_{2L})$ and $p_H = \min(p_{1H}, p_{2H})$. Without loss of generality, we assume that energy and good L are supplied at zero marginal cost while good H is supplied at marginal cost $c > 0$.

We model the production of energy service as a game played by consumers, the energy supplier and the two contractors. The timing of the game is as follows:

1. The energy supplier sets the energy price p_e.
2. The contractors simultaneously set their prices p_{1H}, p_{1L}, p_{2H} and p_{2L}.
3. Each consumer forms a belief about the quality supplied by each contractor and chooses

which good to purchase.

4. Payoffs are realized.

The game is solved by backward induction. We assume throughout that $V > c$ so there is a gain from purchasing good H.

2.2 Equilibrium analysis

Observable quality We start with considering the optimal situation where the quality with which the asset is installed is perfectly observable. We denote with superscript $*$ the resulting equilibrium. In the third stage of the game, the demand for each good is given by the type y of the consumer who is indifferent between purchasing good H and L, such that $u_H(y) = u_L(y)$. Straightforward calculations yield $y(p_H^1, p_H^2, p_L^1, p_l^2, p_e) = (\min(p_H^1, p_H^2) - \min(p_L^1, p_L^2))/p_e$. The demand for L is $y(p_H^1, p_H^2 p_L^1, p_l^2, p_e)$ and the demand for H is $1 - y(p_H^1, p_H^2 p_L^1, p_l^2, p_e)$.

In the second stage, each contractor operates in both the market for good L and H. Since consumers perfectly observe quality, the contractors compete à la Bertrand in each market. They cut price to gain market shares and do so until price equals marginal cost. We therefore obtain $p_H^1 = p_H^2 = c$ and $p_L^1 = p_L^2 = 0$. This implies inverse energy demand $p_e(y) = c/y$.

In the first stage, the energy supplier sets y so as to maximize profit

$$\Pi_e(y) = p_e(y) \int_0^y x dx = \frac{c}{2} y$$

subject to $0 \leq y \leq 1$. Profit is maximized at corner solution $y^* = 1$, hence equilibrium price $p_e^* = c$. In essence, the energy monopolist reduces the energy price until the demand for good H is chocked. Equilibrium energy demand is $\int_0^{y^*} x dx = 1/2$ and $\Pi_e^* = c/2$.

Unobservable quality. We now turn to the case where the quality of installation is unobservable and denote with superscript \$ the resulting equilibrium. In the third stage of the game, consumers are aware of the cost of producing each good but they cannot observe which of the two goods they are offered. Hence they are unwilling to pay any price above zero.

In the second stage, faced with such demand, no contractor is willing to provide good H at price zero. Therefore, only good L is supplied and $p_L^1 = p_L^2 = 0$; this is the classical result for credence good. With only good L in the market, the notion of a consumer indifferent between purchasing good L and good H is no longer relevant. Instead, energy demand will be determined by the consumer of type y who is indifferent between buying good L and not buying at all, such that $u_L(y) = 0$. This yields inverse energy demand $p_e(y) = V/y$. In the first stage, the energy supplier determines the type of the marginal energy user who maximizes profit from energy sales. By the same type of reasoning as in the previous section, this yields $y^\$ = 1$, $p_e^\$ = V$ and $\Pi_e^\$ = V/2$. The equilibrium energy price extracts all surplus from the consumer with the highest energy needs.

The following proposition compares the optimum and the equilibrium.

Proposition 1. *Equilibria with observable vs. unobservable quality compare as follows: (i) in both cases, all consumers buy only good L and consume the same quantity of energy: $y^* = y^\$ = 1$ and $q_e^* = q_e^\$ = 1/2$; (ii) in both cases, contractors make zero profit: $p_{1L}^* = p_{2L}^* = p_{1L}^\$ = p_{2L}^\$ = 0$ and $\Pi_{1L}^* = \Pi_{2L}^* = \Pi_{1L}^\$ = \Pi_{2L}^\$ = 0$; (iii) the energy price and the energy supplier's profit are higher with unobservable quality: $p_e^\$ > p_e^*$ and $\Pi_e^\$ > \Pi_e^*$; (iv) welfare is the same in both cases).*

We obtain the important result that, however observable quality is, only good L is supplied in the asset market. This singular outcome nevertheless hinges upon distinct mechanisms: when quality is observable, the energy supplier strategically keeps the energy price so low as to choke the demand for good H; when quality is unobservable, the energy supplier needs not keep price low and simply extracts all surplus from the marginal buyer of good L. This results in higher energy price − hence higher energy supplier's profit but lower consumer surplus − in the latter case. More generally, total surplus is equal to V in both cases so the quality of information is not a matter of quantity allocation but of surplus distribution.

2.3 Certification as a solution to asymmetric information

One classical solution to unobservable quality is that the regulator creates a public certification. However, as we have seen such instrument would not be here welfare-improving since the welfare is the same under observable and unobservable quality. Another solution is to have a private agent certifying contractors for providing good quality in exchange of a certification fee. A third party can certify contractors. This is for instance the case of voluntary certification programs such as that ran by the Building Performance Institute in the United States. The energy supplier can also certify contractors and then gain on the energy market and on the certification market. We now examine how certification affects the equilibrium with unobservable quality.

In our competition setting, contractors make zero profit if they both supply good H. Certifying both contractors is not individually rational to the certifier, since no certification fee can be charged. The certifier will therefore certify only one contractor: thus enjoying a monopoly rent, the certified contractor will be willing to pay a non-zero certification fee. We assume that consumers are aware of the certification scheme and do not buy good H if uncertified, which preserves the monopoly rent on certified products. The contractors continue to compete à la Bertrand in the market for good L.

In practice, certification labels are not necessarily verifiable. For instance, consumers do not observe whether contractors are randomly and frequently audited by the certifier, as is typically supposed to be the case in certification programs. This raises credibility issues which we examine below.

Let us focus first on the certification by the energy supplier and the latter extracts all the profit of the certified firm.

Truthful certification. We define truthful certification as a scheme that points to good H as of high quality. We denote by superscript t the resulting equilibrium. We consider that contractor 1 provides the two goods while contractor 2 only supplies good L. In the third stage of the game, the type of the indifferent consumer is $y(p_H^1, p_L^1, p_L^2, p_e) = (p_H^1 -$

$\min(p_L^1, p_L^2))/p_e$. In the second stage, the two firms compete à la Bertrand in the market for good L so $p_L^1 = p_L^2 = 0$. Anticipating this, contractor 1 sets price p_H^1 so as to maximize $\Pi_H^1 = (1-y(p_H^1, p_e))(p_H^1 - c) = (1-p_H^1/p_e)(p_H^1 - c)$. The resulting price is $p_H(p_e) = (p_e+c)/2$. What follows is more easily solved when considering energy demand $y(p_e) = (p_e + c)/(2p_e)$ rather than inverse demand, as was previously done. In the first stage of the game, the energy supplier sets p_e so as to maximize profit

$$\Pi_e(p_e) = \int_0^y p_e x dx + \pi_H = \frac{1}{2} p_e (y^*(p_e))^2 + \frac{(p_e - c)^2}{4p_e} = \frac{2(p_e^2 + c^2) + (p_e - c)^2}{8p_e}.$$

Profit is minimized at $p_e = c$. The monopolist will choose the highest feasible price $p_e > c$, subject to the constraints $y(p_e) \leq 1$ and $V \geq p_H \Leftrightarrow p_e \leq 2V - c$. The former constraint is not binding, as this would imply $p_e = c$. The latter constraint will therefore bind and yield equilibrium price $p_e^t = 2V - c$. It follows that $y^t = V/(2V - c) < 1$, that is, the asset market is a vertically differentiated monopoly. Moreover, $p_H^t = V$. The profit of the energy supplier is equal to $\frac{3V^2 - 4Vc + 2c^2}{2(2V-c)}$ which is higher than $\Pi_e^\$$ if and only if $V > 2c$. Certification is profitable if the cost of producing the high quality is relatively low. Otherwise, the profit extracted from the market certification does not offset the losses done on the energy market.

Untruthful certification. We define untruthful certification as a scheme that associates good H with low quality. We denote with superscript u the resulting equilibrium. In essence, untruthful certification induces consumers to bear some energy expenditure upon purchasing good H. This leaves the third stage of the game unchanged.[3] The key difference with truthful certification occurs in the second stage, in which the certified firm now produces at marginal cost zero (i.e., that of good L) instead of c. Maximizing $\Pi_H^1 = (1-p_H^1/p_e)/p_H^1$ yields $p_H(p_e) = p_e/2$ and $y(p_e) = 1/2$. Again, the asset is supplied in a vertically differentiated duopoly. We further obtain the important result that, now, energy consumers are insensitive to the price

[3]In a behavioural perspective, untruthful certification can be interpreted as creating an internality, that is, a wedge between decision utility – that which we focus on – and experienced utility – which we ignore for simplicity.

of energy, since whatever good they buy, they consume energy. Knowing this, in the first stage, the energy supplier covers the entire market, $q_e^u = \int_0^1 x dx = 1/2$, and sets the highest feasible price, i.e., that which extracts all surplus from the indifferent consumer, who enjoys utility $V - p_H(p_e)$. It follows that $p_e^u = 2V$ and $p_{1H}^u = V$. Since $p_e^u > p_e^t$ and $\Pi_H^{1u} > \Pi_H^{1t}$, it is immediate that certification is not credible since the profit of the energy supplier is higher under untruthful than under truthful certification.

Does the third party certify? We wonder whether a third party would have interest in certifying. The energy supplier program would be different in the first stage of the truthful certification. Thus, the energy supplier sets p_e so as to maximize profit

$$\Pi_e(p_e) = p_e \int_0^{y(p_e)} x dx = \frac{(p_e + c)^2}{8p_e}.$$

which leads also to the energy price equal to $2V - c$. The untruthful certification would not be changed. Depending on its bargaining power, a third party would charge a certification fee within $(0, \Pi_H^t]$. Certification would be truthful in equilibrium if it is in contractor 1's self-interest. Comparing equilibrium profits

$$\underbrace{0}_{\Pi_1^\$} < \underbrace{\frac{(V-c)^2}{2V-c}}_{\Pi_1^t} < \underbrace{(V-c)\frac{V}{2V-c}}_{\Pi_1^u}, \tag{1}$$

we see that this is not the case. In words, certification is profitable (the left inequality) but not credible (the right inequality). Consumers will anticipate this and distrust certification.

The proposition below summarizes the results associated with certification.

Proposition 2. *Truthful certification does not emerge in equilibrium, be it provided by a third party or the energy supplier.*

3 Utility energy efficiency programs

We consider the case where the quality is not observable and the regulator implements a cap on energy sales denoted by $E < 1/2$. To reduce its sales, the energy supplier has three instruments at its disposal: increasing energy prices, certifying high quality durable good and subsidizing the purchase of high quality durable good. Let us focus first on the first option that is the basic compliance.

3.1 EEP as a cap on energy sales

First of all, as an alternative benchmark let us focus on the observable quality case. We still denote with superscript u the resulting equilibrium. Introducing such a constraint modifies the energy supplier's maximization program but does not modify the programs of other agents. In other words, only the first stage of the game is modified. As in Section 2.2, the profit of energy supplier is given by

$$\Pi_e(p_e) = \int_0^y p_e x dx = \frac{1}{2} p_e (y^*(p_e))^2 = \frac{c^2}{2p_e}.$$

The single difference is that the energy supplier faces the constraint that $q_e < E$. As in Section 2.2, the energy provider has incentives to sell as much as possible. We deduce that the energy provider has incentive to fix the energy price such that the pivotal consumer is equal to $y^*(E) = \sqrt{2E}$, which leads to $p_e^*(E) = \frac{c}{\sqrt{2E}}$. The consumers whose energy needs are higher than y^* purchase high quality good. Implementing a cap on energy sales obviously increases the energy price and reduces the profit of energy supplier. It also induces the provision of the high quality durable good. The energy supplier cannot anymore strategically impede the good quality to enter into the market.

3.2 Compliance with price

Let us turn back to the unobersvable quality case. We still denote with superscript \$ the resulting equilibrium. In the first stage of the game, as in Section 2.2, the profit of energy supplier is given by

$$\Pi_e(p_e) = \int_0^y p_e x dx = \frac{1}{2} p_e (y^*(p_e))^2 = \frac{c^2}{2p_e}$$

The single difference with the case in Section 2.2 is that the energy supplier faces the constraint that $q_e < E$. The energy provider has incentives to sell as much as possible. We deduce that the energy provider has incentive to fix the energy price such that the pivotal consumer is equal to $y^{\$}(E) = \sqrt{2E}$, which leads to $p_e^{\$}(E) = \frac{V}{\sqrt{2E}}$ and $\Pi_e^{\$}(E) = \frac{V\sqrt{E}}{\sqrt{2}}$. The consumers whose energy needs are higher than $y^{\$}(E)$ do not purchase any good.

The following proposition compares the two previous cases.

Proposition 3. *Equilibria with observable vs. unobservable quality compare as follows: (i) in the observable case, consumers buy good L and good H while in the unobservable case, consumers only purchase good L; (ii) the energy supplier sells the same quantity of energy in both cases $y^*(E) = y^{\$}(E) = \sqrt{2E}$ and $q_e^*(E) = q_e^{\$}(E) = E$; (iii) in both cases, contractors make zero profit: $p_{1L}^*(E) = p_{2L}^*(E) = p_{1L}^{\$}(E) = p_{2L}^{\$}(E) = 0$ and $\Pi_{1L}^*(E) = \Pi_{2L}^*(E) = \Pi_{1L}^{\$}(E) = \Pi_{2L}^{\$}(E) = 0$; (iv) the energy price and the energy supplier's profit are higher with unobservable quality: $p_e^{\$}(E) > p_e^*(E)$ and $\Pi_e^{\$}(E) > \Pi_e^*(E)$; (v) welfare is lower with unobservable quality than with observable quality.*

The profit is higher under unobservable quality than under observable quality since the energy price is higher under unobservable quality than under observable quality. The quantity sold by the energy provider is the same in the two cases. However, the welfare is lower since the consumers whose energy needs are higher than y^* do not consume. Thus, a public label would be Pareto-improving.

3.3 Compliance with price and certification

We consider the case where the energy supplier certifies the high-quality good so that it sets a fee which extracts all the surplus from the certified firm. As in Section 2.3, it is rational for the certifier to certify only one firm and the other one has no incentives to provide the high-quality. Let us focus first on the truthful certification and later on the untruthful one.

Truthful certification. We denote by superscript t the resulting equilibrium. The resulting pivotal consumer is given by $y(p_e) = \frac{p_e+c}{2p_e}$. At the first stage, let us consider the energy supplier's decision. Its profit is given by

$$\Pi_e(p_e) = \int_0^y p_e x dx + \pi_H = \frac{1}{2}p_e(y^*(p_e))^2 + \frac{(p_e-c)^2}{4p_e} = \frac{2(p_e^2+c^2)+(p_e-c)^2}{8p_e}$$

Indeed, the difference with the case of the certification by a third party is the gain due to the certification fees, which is equal to π_H. The profit function is minimized at $p_e = c$. The problem has twp potential corner solutions. As previously, the condition $V \geq p_H$ implies that the highest energy price is $2V - c$ and the condition $\int_0^{y(p_e)} xdx < E$ implies that the energy has to satisfy the obligations on energy sales. The pivotal consumer associated to the equilibrium $p_e^t = 2V - c$ is given by $y^t(E) = \frac{V}{2V-c}$. If $y^t = \frac{V}{2V-c} < \sqrt{2E}$, then the equilibrium is given by $p_e^t = 2V - c$. Otherwise, the price is given by the equality $y(p_e) = \frac{p_e+c}{2p_e} = \sqrt{2E}$ and we deduce $p_e^t((E)) = \frac{c}{2\sqrt{2E}-1}$.

The following lemma summarizes the results.

Lemma 1. *There are two possible cases depending on the stringency of the cap: (i) If* $E > \frac{V^2}{2(2V-c)^2}$*, the two qualities are provided,* $p_e^t = 2V - c$*,* $y^t = \frac{V}{2V-c}$*,* $\Pi_e^t = 3V^2 - 4Vc + 2c^2\frac{}{2(2V-c)}$*,* $p_L^{1t} = p_L^{2t} = 0$ *and* $p_H^{1t} = V$*; (ii) If* $E < \frac{V^2}{2(2V-c)^2}$*, the two qualities are provided,* $p_e^t(E) = \frac{c}{2\sqrt{2E}-1}$*,* $y^t(E) = \sqrt{2E}$*,* $\Pi_e^t(E) = (\frac{3E-2\sqrt{2E}+1}{2\sqrt{2E}-1})c$*,* $p_L^t(E) = 0$ *and* $p_H^t(E) = \frac{\sqrt{2E}c}{2\sqrt{2E}-1}$*.*

In order p_e^* to be positive, we assume that $E > \frac{1}{8}$. The more stringent the cap is, the higher the energy price will be. Consider for a moment case (ii). The energy price is always lower than the one with unobservable quality. Since the energy supplier sales the same quantity, the gain made only on the energy market is lower with certification than without. Let us now determine whether certification is credible. To do so, let us focus on the untruthful certification.

Untruthful certification. Consumers believe that the certified product is of high quality while in reality it is of low-quality durable good. As we have seen in the case of a certification made by a third-party, the pivotal consumer does not depend on the decisions of the energy supplier, such that $y^u(p_e) = \frac{1}{2}$. The energy supplier has to satisfy the constraint and is prevented from cheating. The following proposition determines whether certification is profitable and credible.

Proposition 4. *Certification by the energy supplier is profitable if either c is sufficiently weak and the cap sufficiently lenient or the marginal cost sufficiently high and the cap sufficiently lenient. Certification by the energy supplier is credible.*

First, when the cap is higher than $\frac{V^2}{2(2V-c)^2}$, the truthful certification leads to energy sales lower than the cap and the profits are the same in the truthful certification without cap on the sales when the marginal cost is weak. The sum of the two streams of revenue are higher than the profit made by the energy supplier when it uses only the price adjustment to comply with the obligations. Second, when the cap is lower than $\frac{V^2}{2(2V-c)^2}$, the cap is binding. The energy and the certified product prices increase with the marginal cost of production and decrease with the cap.When the marginal cost is sufficiently high and the cap sufficiently lenient, the profit of the energy supplier is higher than without certification. The cap on energy sales makes the certification credible since consumers anticipate that the energy supplier is forced to reduce its sales and therefore cannot lie about the environmental quality of energy efficiency contractors.

3.4 Compliance with subsidies

We wonder whether the energy provider has incentives to grant investment subsidies in order to comply with the cap on the energy sales. First of all, let us consider the case where the energy provider can use subsidies without using certification. Under unobservable quality case, supplying high quality is not credible and the subsidy should be equal to the difference in prices between the high and the low quality. Since competition is "à la Bertrand", the difference is equal to c. The first question is which consumers should be pushed to consume quality H. If the consumers with the highest needs are prevented from consuming electricity, the energy price will be the same as in the unobservable quality case and the energy provider will additionally bear costs. In other words, it is preferable to increase prices to comply with the cap on emissions instead on subsidizing the purchase of high quality.

Second, let us consider the case where the energy provider can use subsidies and certification at the same time. We wonder whether the energy provider can increase its profits by subsidizing the purchase of certified high quality. We denote by s the subsidy given by the energy supplier to the consumer who purchases the certified good. The resulting pivotal consumer contingent on p_e is $y(p_e) = \frac{p_H^1 - s}{p_e}$. The demand for quality H is given by $1 - \frac{p_H^1 - s}{p_e}$ which leads to $\pi_H^1 = (1 - \frac{p_H^1 - s}{p_e})(p_H^1 - c)$. The resulting price contingent on p_e is $p_H(p_e) = \frac{(p_e + c + s)}{2}$, leading to $y(p_e) = \frac{p_e + c - s}{2p_e}$. Reasoning backward, consider now the energy supplier's decision. Its profit is given by

$$\Pi_e(p_e) = \int_0^y p_e x dx + \pi_H - (1 - y^*)s = \frac{1}{2} p_e (y^*(p_e))^2 + \frac{(p_e - c)^2 - s^2}{4p_e} = \frac{(p_e + c - s)^2}{8p_e} + \frac{(p_e - c)^2 - s^2}{4p_e}$$

which decreases with s. We deduce the energy supplier has no incentives to distribute subsidies to promote certified durable goods. The following proposition summarizes these results.

Proposition 5. *The energy supplier does not use subsidies to comply with the cap on the energy sales.*

3.5 Welfare analysis

The introduction of a cap on electricity sales pushes the energy supplier to certify high-quality product under some conditions. The organization of the market for sustainable goods is modified. We can therefore wonder about the effects of certification in terms of the well-being of society. First, we calculate the costs and benefits to society generated by this new organization in relation to the case where the information remains asymmetric. Relative to the case in which quality is not observable, when there is certification consumers with the highest needs are better-off since they are not rationed. The gain for society of non rationing consumers is $(1 - y^*)V$. However, firm 1 produces high quality and bears a cost $(1 - y^*)c$. Moreover, when certification is not profitable we have seen that a public label would also be welfare-improving since the welfare with observable quality is higher than the welfare with unobservable quality. We deduce then the following proposition.

Proposition 6. *The certification by the energy supplier or by the regulator is welfare-improving.*

4 Extensions and robustness checks

Exogenous energy prices. Until now, we have considered that the energy supplier was in a monopoly situation. To meet the sales reduction obligations, the latter could use the price to satisfy the constraint. However, some States operate on this market and prices are regulated. Moreover, when competition is perfect on the energy market, prices are exogenous. We consider here the case where prices are endogenous. If the regulated prices are sufficiently low, it is impossible for the utility to satisfy the constraint on sales without using demand side management. Indeed, when quality is either observable or unobservable, without adjusting the price, the electricity supplier cannot reduce its sales. When the energy supplier certifies a contractor, it reduces electricity sales but cannot adjust its price. Certifying and extracting the contractor's surplus is profitable for the electricity supplier. If the price is above a certain threshold, to satisfy the constraint on energy sales, the energy supplier must use subsidies to reduce its sales, which is costly for it. Thus, for small reductions in energy sales, the energy supplier uses certification. For larger reductions it uses certification and subsidies.

Exogenous qualities of durable goods. We also assumed that companies can decide on the quality provided. Consider the case where the qualities are exogenous and two companies are present on the market: one providing good quality while the other provides poor quality. We assume that good of low quality is supplied at zero marginal cost while the high quality good is supplied at marginal cost $c > 0$. In such a case, we show that the results obtained hold. However, the economic mechanisms are different. The company with poor quality may decide to reveal its quality by setting a price below the marginal cost of production of its competitor. When quality is observable, both qualities can be produced and in this case there is a differentiated duopoly. When quality is unobservable, it is better for the poor quality company not to reveal itself and therefore the information remains asymmetric. Both qualities are present on the market but the consumer cannot discern them. Certification is a means of informing consumers. We show that providing certification is more profitable to a third party than to the energy supplier, but none of these certifications is credible if the energy supplier is not subject to sales reduction obligations. On the other hand, the introduction of such obligations makes the certification by the energy supplier credible, while certification by a third party is still not credible.

Firms label. So far we have assumed that certification is about a product and not a company. Thus, the company can offer a certified and a non-certified product. However, some labels certify companies and not products. The results qualitatively are not affected for the energy supplier strategy by such an assumption. However, if the certifier implements a firm label, the non certified firm makes a positive profit. The certification by a third party without energy saving obligations may be credible since the profit made by the certified firm under untruthful certification is lower than with product label.

5 Conclusion

This paper demonstrates that under the lack of obligation, the impossibility of observing quality prevents firms from producing good quality and allows the energy producer to increase its sales. The latter has no interest in distributing subsidies to promote good quality but certifying a product as good quality is beneficial for the energy producer if the marginal cost of production of high-quality is sufficiently weak. The certification is nevertheless not credible because consumers anticipate that it is in the consumer's interest to certify a product of poor quality as good. For a third party too, certification is profitable but not credible. When the regulator imposes restrictions on the energy supplier's sales, the best response of the energy supplier is either to only adjust energy prices or to adjust energy prices and certifying a high-quality product. It is under specific conditions in the energy supplier's interest to certify the product of good quality to meet this obligation. Certification is credible because consumers anticipate that the energy provider has no interest in certifying a poor quality product instead because it could no longer comply with the constraint. On the other hand, certification by a third party is still not credible. Finally, certification by the energy provider is welfare-improving. When certifying high quality is not in the energy supplier's interest, implementing a public label is welfare-improving. When the energy supplier can adjust energy prices, it has never interest to grant investment subsidies. When the energy market is either competitive or regulated, the energy supplier has incentives to grant subsidies when the level of stringency of the regulation is sufficiently great. In such a case, granting subsidies is also welfare-improving.

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